

Cryogenic Systems for the Large Deployable Reflector

Peter V. Mason
Jet Propulsion Laboratory
Pasadena, CA 91109

There are five technologies which may have application for LDR, one passive and four active. In order of maturity, they are passive stored cryogen systems, and mechanical, sorption, magnetic, and pulse-tube refrigerators. In addition, deep space radiators will be required to reject the heat of the active systems, and may be useful as auxiliary coolers for the stored cryogen systems. Hybrid combinations of these technologies may well be more efficient than any one alone, and extensive system studies will be required to determine the best trade-offs.

Stored cryogen systems have been flown on a number of missions. They are capable of meeting the temperature requirements of LDR; superfluid helium systems provide temperatures as low as 1.2 K, and its boil-off gas can probably provide the necessary cooling at higher temperatures. Stored solid neon systems can provide temperatures as low as 15 K. (Solid hydrogen can provide about 10 K, but it involves severe safety issues.)

The size and weight of stored cryogen systems are proportional to heat load and, as a result, are applicable only if the low-temperature heat load can be kept small. With a heat load of a few hundred milliwatts, replenishment will be required at about three year intervals. If instrument changeout is required, this will not add greatly to the complexity of orbital operations. NASA is now preparing a demonstration of the technology to transfer superfluid helium in orbit, and a 10,000 liter tanker, capable of being lifted to a high orbit, is under development. If the heat load at 2-4 K is <300 mW, and replenishment at three year intervals is acceptable, stored cryogen systems may meet LDR needs.

Mechanical refrigerators have had wide application in ground-based systems. A number of machines capable of delivering 10 K exist and can be fitted with a Joule-Thomson expander to provide temperatures in the 2-4 K range. They will require substantial power and heat radiating capability. Rough estimates suggest a total power drain of 5-10 kW, and radiators capable of handling an equal amount of power at 200-300 K.

Demonstrated system lifetime without maintenance for conventional 10 K mechanical refrigerators is about one to two years. A 60 K system using magnetic bearings, sponsored by GSFC, has demonstrated a lifetime of two years with no degradation, but it is not clear that a 10 K system can be built on the same principles. There has been a large investment by NASA and the USAF to arrive at the present capability and, without a very large additional infusion of money, it is unlikely that a ten-year lifetime will be available for a project start in the mid-nineties. Various schemes have been proposed to overcome the inherent unreliability of mechanical refrigerators. One such

scheme would fly several refrigerators with heat switches to allow replacement of a failed unit with a functioning one.

Systems using chemisorption and physical adsorption for compressors and pumps have received considerable attention in the past few years. They are expected to be reliable and noise-free, but have relatively poor efficiencies. A major effort is now underway at JPL to develop a system capable of delivering 60-80 K. Some attention has been given to schemes capable of delivering temperatures below 10 K. Multistaging and use of new fluid-absorbent combinations will be required. Careful evaluation of expected efficiencies is required. Since there are few or no moving parts, lifetime is expected to be long, but this remains to be demonstrated. Such a demonstration is part of the current JPL research program.

Systems based on adiabatic demagnetization of paramagnetic salts have been used for refrigeration for many years. In the past they have been limited to temperatures below a few kelvin, but current investigations are likely to result in cycles working up to 20 K. In addition, the use of the new high T_c superconductors may increase efficiency and allow operation at higher temperatures.

Current designs function in one of two ways: either the salt is moved mechanically in and out of the field, or the field of a superconducting magnet is ramped up and down. Mechanical motion leads to concerns about reliability. However, current designs use low speed rotation on standard bearings and have the potential for long life. In the past, ramping the superconducting magnetic field required heat dissipation at low temperatures, resulting in the need for substantial refrigeration capacity. Use of high- T_c superconductors may reduce refrigeration requirements substantially. However, the new superconductors cannot as yet carry the necessary current in the wire form needed for magnets. Several years of research will be required to solve this problem.

Pulse-tube refrigerators have recently been proposed which show relatively high efficiency for temperatures in the 60-80 K range. They are simple and should be reliable. They are candidates for higher temperature cooling, which will be necessary for any of the active schemes, and may be useful in reducing the size and weight of a stored cryogen system. A modest program of such is now underway, which should resolve whether pulse tube refrigerators are viable candidates. To sum up:

- o The instrument heat loads and operating temperatures are critical to the selection and design of the cryogenic system. Every effort should be made to minimize heat loads, raise operating temperatures, and to define these precisely.

- o No one technology is now ready for application to LDR. Substantial development efforts are underway in all of the technologies discussed and should be monitored and advocated. Magnetic and pulse-tube refrigerators have high potential. They are the least well defined, and should be assessed by detailed studies.